Supplementary material

Observation of photovoltaic effect in a van der Waals heterostructure

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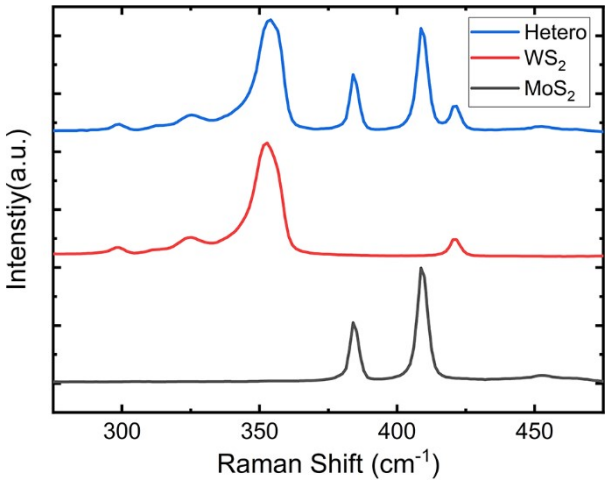

Fig.S1 Raman spectra of WS_2/MoS_2 measured at different locations with an excitation laser wavelength of 532 nm.

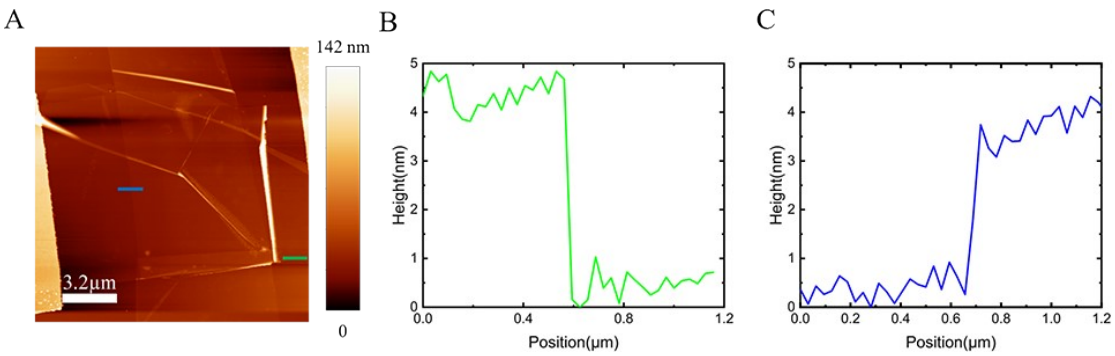

Fig.S2 AFM image of WS_2/MoS_2 (A) and height profiles of MoS_2 (B) and WS_2 (C). The height profiles of MoS_2 and WS_2 correspond to blue and green lines in (A), respectively.

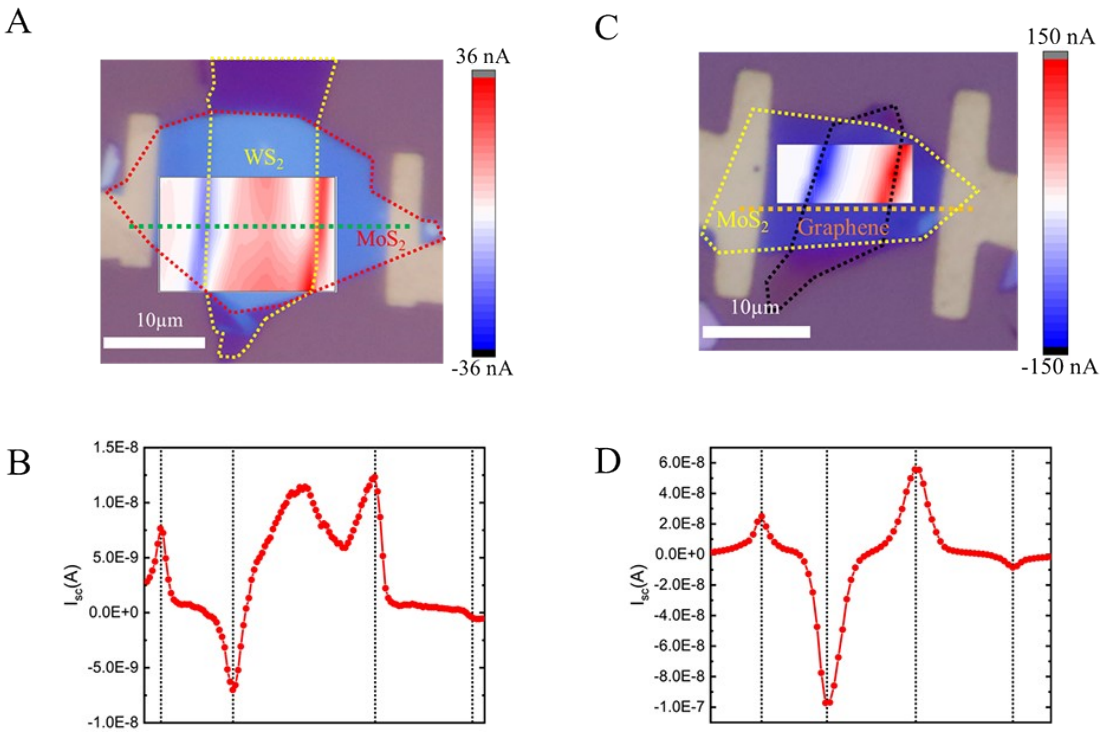

Fig.S3 Photocurrent maps of (A) another WS_2/MoS_2 and (C) Graphene/MoS_2. Line profiles along (B) the green dotted line shown in (A) and (D) the orange dotted line shown in (C). Dotted lines in (A) and (C) are outlines of WS_2, MoS_2, and graphene flakes.

Supplemental discussion about a built-in potential effect

Although the KPFM observation ruled out in-plane built-in potential, an out-of-plane built-in potential probably exists due to unintentional doping and type-II band alignment of WS_2/MoS_2. This out-of-plane built-in potential causes a chemical potential difference between WS_2 and MoS_2 in response to light excitations, leading to a continuous photocurrent when WS_2 and MoS_2 contact electrodes, respectively. Indeed, this type of out-of-plane photocurrent has been observed in, for example, a MoS_2/WSe_2 heterostructure (*Nano Lett.* 14, 8, 4785 (2014)). Because the built-in potential drives the out-of-plane photocurrent, I-V characteristics show asymmetric curves, which are distinctly different from the linear curves observed in our study. Furthermore, as shown in Figs. 1 B and C, only MoS_2 directly contacts the source and drain electrodes in our device. In this case, the out-of-plane chemical potential difference can not contribute to the lateral photocurrent flowing through the MoS_2 flake. Therefore, we can safely conclude that the photocurrent observed in this study is not driven not by a built-in potential.

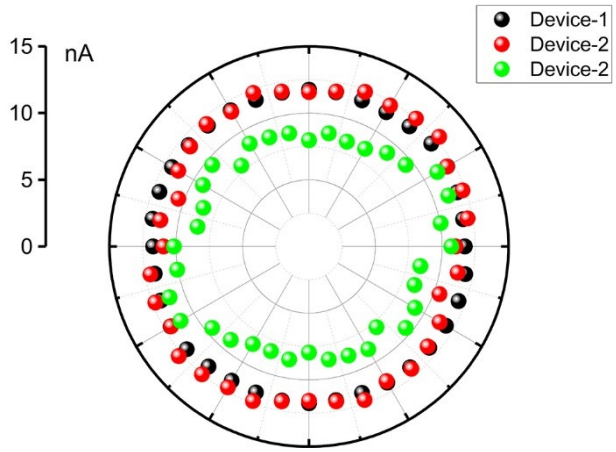

Fig.S4 Polar plots representing polarization direction dependences on photocurrent measured at the WS_2/MoS_2 regions of two different devices.

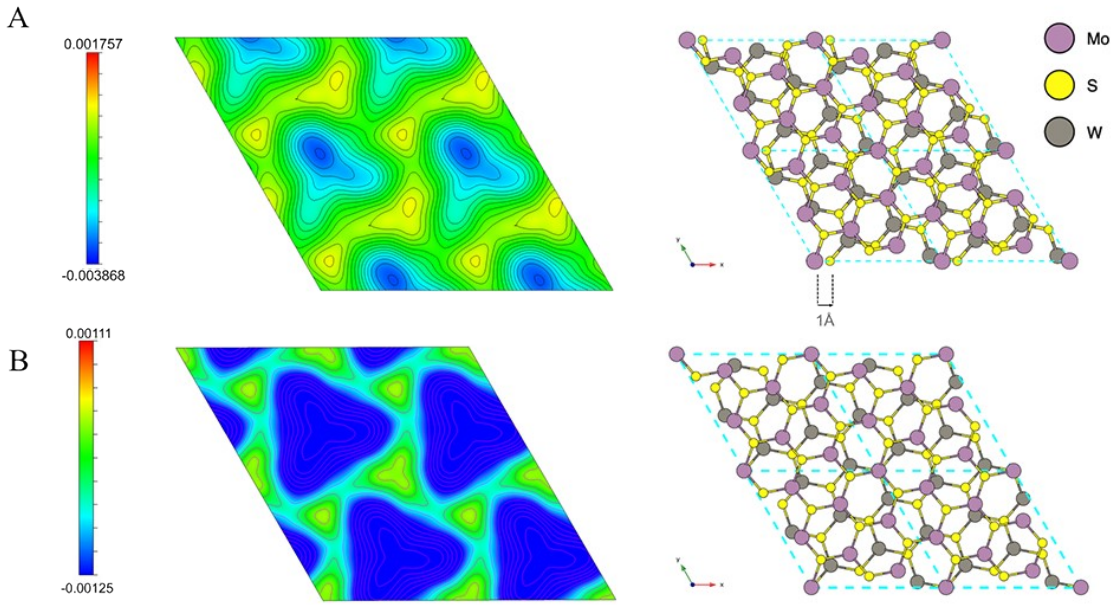

Fig.S5 2D electrostatic potential profiles of twisted WS_2/MoS_2 with different translational shifts. The structure shown in (A) does not have a C_3 axis, whereas the structure shown in (B) has a C_3 axis.